STRATIGRAPHICAL GEOLOGY OF THE PERMO-CARBONIFEROUS SYSTEM IN THE MAITLAND-BRANXTON DISTRICT,

WITH SOME NOTES ON THE PERMO-CARBONIFEROUS PALÆOGEOGRAPHY IN NEW SOUTH WALES.

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(Plates viii.-xiii., and ten text-figures.)

This paper is the result of about four months' fieldwork in the Hunter River District, the area examined during that period being bounded on the north by the Hunter River, and on the other three sides roughly by a line drawn through West Maitland, Mt. Vincent, Mt. View, and Belford, and also a small area north of the Hunter River, between West Maitland and Paterson.

The most important work done on this area is Professor David's memoir on "The Geology of the Hunter River Coal-Measures of New South Wales."* In that work, the coal-measures are worked out in detail, but the Lower Marine Series and the Upper Marine Series are not treated in as great detail as the coal-bearing series. It was with the object of obtaining a more detailed knowledge of these two marine series, that this work was done. One portion of the outcrop of the Greta Coal-Measures, namely, that extending south from Branxton, was not very well-known at the time Pro-

* Mem. Geol. Survey N. S. Wales, Geology No.4, 1907.

fessor David's work was published; but since then, a good deal of prospecting has been done along this part of the outcrop, and fresh information was obtainable, and is included in this paper.

To make the lists of fossils as complete as possible, fairly large collections were made, and these have been supplemented by records of localities of fossils, from the publications of the Geological Survey of New South Wales, and from the "Catalogue of Australian Fossils," by R. Etheridge, Jr. In many cases, however, the record of the locality of fossils is not definite enough to permit of their horizon being determined. Only cases where the locality is sufficiently definitely stated, have been used in completing these lists. The map which accompanies the paper (Plate ix.) is part of Professor David's Map of the Hunter River Coal-Measures, published by the Geological Survey of New South Wales, in 1907, with additions which have resulted from my field-work.

Lower Marine Series.

The development of the Lower Marine Series varies considerably in different parts of the district; vertical sections have been obtained in three places, and are shown in Figs. 1-3. In Fig. 1 (p. 116), which gives the most typical section, and that in which the series is most completely represented, the series attains a thickness of nearly 4,800 feet. This section is taken from the occurrences in the area between Farley, Greta, and Cessnock. Fig. 2 (p. 117) gives the succession near the Carboniferous inlier of Mt. Bright, where there is a considerable overlap of the lower beds. Fig. 3 (p. 118) is taken along the Eelah Road, where there is also a considerable overlap.

The group of hills about one mile south-east of Lochinvar Township, of which Winder's Hill is the most prominent, is composed of a varied series of rocks of Carboniferous age. They include a variety of volcanic rocks, both acid and intermediate; and also sedimentary rocks, such as conglomerate, sandstone, and yellowish cherty tuff. These sedimentary rocks, in places, contain abundant plant-remains, such as *Rhacopteris,* which indicate that they are of Upper Carboniferous age.

Skirting the southern end of these Carboniferous rocks are the lowest beds of the Permo-Carboniferous System that occur in the Hunter River District, namely, the Lochinvar glacial beds. These can be traced, almost continuously, from a point just west of the village of Gosforth round to a point about half a mile south of the Hunter River, on the road from Lochinvar to Windermere, a total

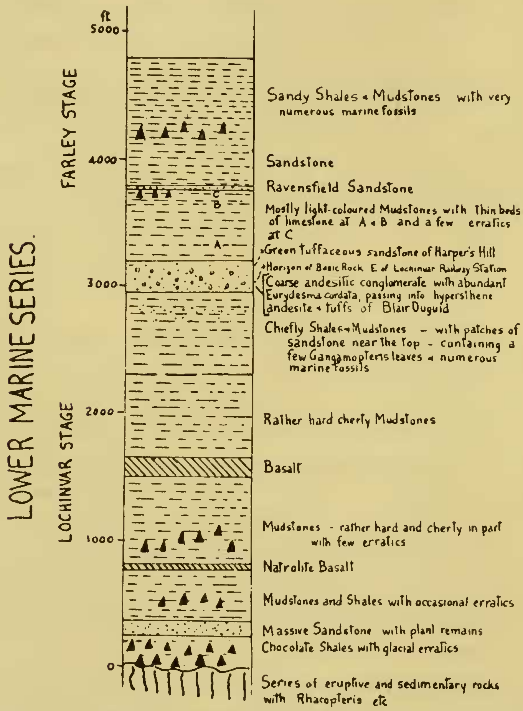

Fig.1.—Vertical Section of Lower Marine Series in the Farley-Greta District.

distance of about five miles. In places, they are distinctly unconformable with the underlying beds. In portions 5 and 6, Parish of Gosforth, the Carboniferous rocks strike 225°, and dip to the south-east at high angles (58°-64°); and the strike of the glacial beds varies between 195° and 170°, and they dip at low angles (15° to 8°). They have been described by Professor David,* and consist of fine-grained, reddish-brown to chocolate-coloured shales, containing numerous boulders up to about 2 feet in diameter. Very many of these boulders are waterworn, but some are undoubtedly striated and faceted as a result of ice-action. Their thickness varies, a section near the north-west corner of portion 13, Parish of Gosforth, gives their thickness as about 150 feet, but further south, on Windella Estate, they are quite 250 feet thick. There is a good outcrop on the road from Lochinvar to Windermere, but the lower limit there is hidden under recent alluvial, so that the thickness is not determinable. No marine fossils have ever been found in these shales. The glacial beds are not found on the northern side of the Hunter River. At the eastern end of the Carboniferous rocks, near Eelah, they are overlapped by higher members of the Lower Marine Series; while, at the western end of the Carboniferous complex, the Eldersleе fault has thrown the Upper Coal-Measures down against the Carboniferous.

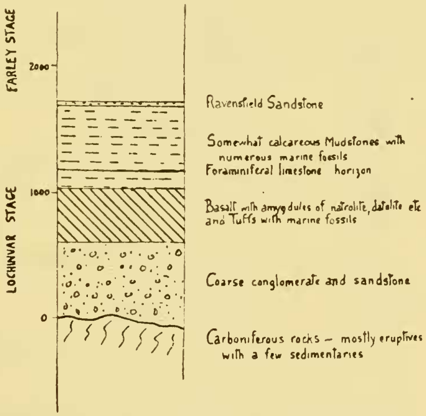

Fig. 2.—Vertical Section in the vicinity of Pokolbin and Mt. View.

Immediately overlying the chocolate shales, is a massive sandstone, about 100 feet thick; and no marine fossils have yet been reported from this. Careful search was made, at several points, in this sandstone for marine fossils, but without success. It contains, however, numerous plant-remains. There is a possibility, then, that this lowest part of the Lower Marine Series is of freshwater

* Journ. Proc. Royal Soc. N. S. Wales, 1899, xxxiii., pp. 154-159.

origin. As a new and extensive occurrence of the glacial beds has recently been described from the Kempsey District,* it would perhaps be as well to leave any further discussion of them until that area has been more fully worked out.

This stage is followed by an enormous development of marine sandstones and mudstones, with which are associated a number of contemporaneous lava-flows. There are, first, about 400 feet of gritty, ferruginous mudstone, followed by a flow of basalt, 50 feet thick, in which numerous small steamholes have become filled with secondary minerals, such as analcite, natrolite, calcite, etc.

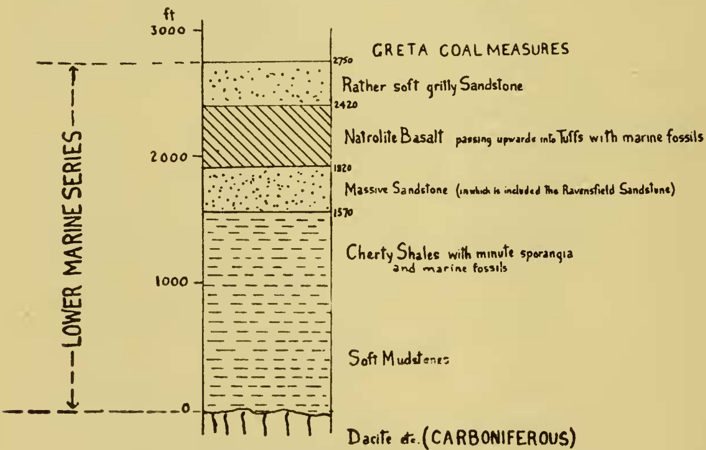

Fig.3.—Vertical Section obtained along Eelah Road.

Then come 700 feet of rather hard shales and mudstones, which contain a few erratics, followed by a basalt-flow, 150 feet thick. This is followed by 1,300 feet of shales and mudstones, which also contain a few erratics, and near the top of which, there are numerous small patches of calcareous sandstone. About 100 feet above the basalt, the shales are somewhat cherty, and contain veins filled with a red secondary material, probably chalcedony.

* W. G. Woolnough, Journ. Proc. Royal Soc. N. S. Wales, 1911, xlv. pp. 159-168.

It is in these beds that the lowest horizon for marine fossils in the series is found. About halfway up the series, and about 2,000 feet from the base of the marine series,* there is a zone in which *Ptycomphalina trifilata, P. nuda,* and *Gangamopteris* are found, the first-named being particularly abundant. This zone is exposed in a small quarry on the road, about half a mile north of Lochinvar Railway Station.

A little higher up in the mudstones, fossils become much more abundant, and the following have been found:—

Tribrachiocrinus sp
Indeterminate crinoid.
Crinoid stems.
Fenestella (?) *internata.*
F.(?) *fossula.*
Stenopora tasmaniensis.
Spirifer duodecimcostata.
S. stokesi.
S. avicula.
Martiniopsis subradiata.
var. *morrisii.*
cf. *morrisii.*
Productus cora var. *farleyensis.*
Strophalosia jukesi.
Chonetes sp.
Edmondia(?) *nobilissima.*
Merismopteria, sp.nov.
Aviculopecten sprenti.
A. tenuicollis.
A. englehardti.
A. sp.
Deltopecten subquinquelineatus.
D. farleyensis.
Mæonia sp.
Pleurophorus.
Notomya(?).
Pachydomus.
Mourlonia.
Ptycomphalina trifilata.
Platyschisma.
Conularia.

In the sandstone patches, near the top of these mudstones, fossils are abundant, and comprise the following:—

Spirifer vespertilio.
S. tasmaniensis.
Martiniopsis subradiata.
Chænomya sp.
Pleurophorus sp.
Pachydomus.
Mourlonia rotundatum.
Keeneia (juv.).

* On p.322 of Professor David's Memoir, this is stated as 3,000 feet; it is probably a misprint, as on the vertical section accompanying that work, it is shown as about 2,000 feet.

Edmondia(?) *nobilissima*. *Conularia lævigata*.
Deltopecten subquinquelineatus. Plant-stems.
Mæonia, 3 spp.

One hundred and fifty feet below the top of these mudstones, (or 2,450 feet above the base of the marine beds), in a band of dark-coloured, sandy, calcareous mudstone, numerous specimens of the pseudomorph Glendonite were obtained. Further details of this are embodied in a separate note.

Following the mudstones, there is a development of a coarse conglomerate with large waterworn pebbles, chiefly composed of andesite, followed by a rather soft gritty sandstone, and then a rather coarse, greenish, tuffaceous sandstone. These together form a thickness of strata of about 250 feet. The conglomerate is known as the Allandale Conglomerate, and contains an abundance of large molluscs with thick shells, such as *Eurydesma cordata, Platyschisma oculus, Keeneia platyschismoides,* etc. The greenish, tuffaceous sandstone is the Harper's Hill Sandstone. These beds are only developed locally in the neighbourhood of Allandale. Towards the south-east, they seem to give place to a development of tuffs associated with the hypersthene-andesite of Blair Duguid Hill. This hypersthene-andesite mass is contemporaneous in the Lower Marine Series; the mudstones can be seen dipping under it at a gentle angle ($9\frac{1}{2}°$-$10°$) on its northern side, and they have practically the same dip at its western end, so that they, apparently, have not been disturbed by the volcanic rock. The centre of eruption must have been somewhere in the vicinity of Blair Duguid Hill, and the activity here was doubtless responsible for some of the blocks of andesite in the Allandale Conglomerate, as well as for the tuffaecous nature of the Harper's Hill Sandstone. The hypersthene-andesite contains a great number of steamholes filled with secondary material, and beautiful specimens of agate, chalcedony, etc., can be obtained. At the eastern end of the mass, near the junction of two creeks in portion 152, Parish of Allandale, masses of chert, up to about 18 inches in diameter, have been floated up in the lava. This chert resembles very much that in which Carboniferous fossils are found near Winder's Hill, and has probably been brought up from some considerable depth, as there would be nearly 3,000 feet of Permo-Carboniferous strata between this horizon and the underlying Carboniferous rocks.

Some distance to the east of Lochinvar Railway Station, there is a large mass of basic rock, which is on a horizon about 2,700 feet above the base of the marine beds; this, then, probably belongs to the same series as the volcanic rocks round Blair Duguid. In the opposite direction, to the north-west, the conglomerate seems to die out quickly, and give place to a thicker development of the Harper's Hill Sandstone, for there is no outcrop of the conglomerate on the main road to Singleton, going up Harper's Hill. Fossils are very numerous in these beds; in the railway-cutting, just over half a mile east of Allandale, there is a bed about 2 to 3 feet thick, composed mostly of the remains of thick shells like *Eurydesma cordata* and *Platyschisma*. The following is a list of fossils from these beds:—

Crinoid stems.
Stenopora tasmaniensis.
S. all. *tasmaniensis.*
S. ovata.
Fenestella(?) *fossula.*
Polypora.
Dielasma hastata.
D. sacculus.
Martiniopsis subradiata.
    var. *morrisii.*
    cf. *morrisii.*
Spirifer vespertilio.
S. stokesi.
S. tasmaniensis.
S. clarkei.
S. sp.ind.
Solenopsis sp.
Chænomya etheridgei.
C. sp.
Allorisma curvatum.
Aviculopecten tenuicollis.
A. squamuliferus.
A. mitchelli.
A. sprenti.
A. sp.ind.
Deltopecten illawarrensis.
D. fittoni.
D. limæformis.
Eurydesma cordata.
Aphanaia sp.ind.
Modiola crassissima.
Pleurophorus sp.ind.
Orthonota sp.
Notomya sp.
N. cuneata.
Pachydomus antiquatus.
P. lævis.
P. ovalis.
Orthonychia altum.
Platyceras, n.sp.

Edmondia(?) *nobilissima.*
Palæarca subarguta.
Merismopteria macroptera.
M. n.sp.
M. sp.ind.
Avicula intumescens.
Ptycomphalina trifilata.
P. morrissiana(?).
Keeneia platyschismoides.
Platyschisma oculus.
P. depressa.
Conularia inornata.
C. lævigata.

Following the Harper's Hill beds, there are 560 feet of light-coloured mudstones, with two horizons of limestone-bands. The mudstones are somewhat calcareous, but, in the outcrops from which this section was obtained, they contain few fossils. Further south, however, near Pokolbin, there are numerous fossils in them (see later p.125). At about 130 feet above the base of the mudstones, there occur in several localities (marked *a* on the map) limestone-bands containing marine fossils, amongst which Fenestellidæ are abundant. The following fossils occur on this horizon :—

Stenopora.
Fenestella(?) *fossula.*
F.(?) *internata.*
Spirifer.
Aviculopecten squamuliferus.
Platyschisma.
Euomphalus(?).
Ptycomphalina.

In the cuttings, along the road from Allandale Railway Station to the main northern road, a number of small faults can be seen, which, however, cannot be traced on the surface. They appear to be a series of step-faults, with small throws to the north-east.

At 420 feet from the base of the same mudstones, there is another series of limestone-concretions at several places (marked β on the map), but these contain only very few fossils.

Almost at the top of these beds, just below the Ravensfield Sandstone, in portions 46 and 47, Parish of Heddon, there are a number of large granitic erratics.

The mudstones are the topmost beds of the Lochinvar Stage, and are followed by the Ravensfield Sandstone, the lowest beds of the Farley Stage.

The Farley Stage commences with the well-known Ravensfield Sandstone. This sandstone forms a very persistent horizon, and is from 12-20 feet thick. In the vicinity of Farley Railway Station, there is a considerable development of massive sandstone, reaching perhaps 200 feet in thickness, part of which is the Ravensfield Sandstone. The part which corresponds to the Ravensfield Sandstone, and which has been quarried for building-stone, is about the middle of this massive sandstone. It is difficult, however, to make a division-line in this sandstone, and the whole of it has here been included with the Farley Stage. A similar occurrence is met with on the Eelah Road, and will be described later(p.126). There are numerous conglomerate patches in the Ravensfield Sandstone, and they contain a varied and abundant marine fauna, amongst which are the following :—

Lasiocladia.
Palæaster clarkei
P. stutchburii.
P. giganteus.
Fenestella(?) *fossula.*
F.(?) sp.
Dielasma cymbæformis.
D. biundata.
D. sp.
Spirifer tasmaniensis.
S. duodecimcostata.
S. sp.
Cyrtina(?).
Martiniopsis subradiata.
  var. *morrisii.*
Solenopsis sp.
Cardiomorpha(?).
Chænomya mitchelli.
C. etheridgei.
C. n.sp.
Edmondia(?) *nobilissima.*
Aviculopecten squamuliferus.
A. profundus.
Aviculopecten tenuicollis.
A. sprenti.
A. mitchelli(juv.).
Deltopecten limæformis.
D. subquinquelineatus.
D. farleyensis.
D. fittoni.
Eurydesma cordata.
  var. *ovale.*
Mæonia carinata.
Pleurophorus.
Pachydomus.
Astartila corpulenta.
Lamellibranch (new genus).
Platyceras altum.
Platyschisma.
Ptycomphalina trifilata.
Conularia tenuistriata.
C. inornata.
Hyolithes lanceolatus.
Goniatites micromphalus.
Orthoceras, 2 spp.

Perhaps the best outcrop of this is to be seen at Browne's Ravensfield Quarry, about three miles south-west from Farley Railway Station, where good collections can be obtained.

These sandstones are followed by a series of sandy shales and mudstones, and the whole stage attains a thickness of from 800 to 1,000 feet. The mudstones are, in general, light-coloured, but some bands are much impregnated with iron, and have become stained quite red. Fossils are very numerous, and good collections can be obtained from both the road and railway-cuttings near Farley Railway Station. The following is a list of fossils from the Farley beds:—

Dielasma sacculus.	*Edmondia*(?) *nobilissima.*
D. cymbæformis.	*Aviculopecten squamuliferus.*
D. biundata.	*A. tenuicollis.*
D. amygdala.	*A. sprenti.*
D. inversa.	*A. englehardti.*
D. hastata.	*Aphanaia* sp.
Spirifer duodecimcostata.	*Mytilus bigsbyi.*
S. stokesi.	*Modiolopsis.*
S. tasmaniensis.	*Mæonia.*
Martiniopsis subradiata.	*Pleurophorus* sp.
var. *morrisii.*	*P. gregarius.*
var. *konincki.*	*Stutchburia farleyensis.*
Productus cora var. *farleyensis.*	*Pachydomus.*
P. fragilis.	*Platyschisma oculus.*
Rhynchonella.	*P. rotundatum.*
Chonetes.	*Conularia inornata.*
Cardiomorpha gryphioides.	*Goniatites micromphalus.*

In the upper 200 feet of these beds, *Nuculana waterhousei*, which does not appear in the lower part, is of fairly frequent occurrence.

An interesting and somewhat different vertical section is obtained in the vicinity of Pokolbin and Mt. View (Fig.2). More than 2,000 feet of the Lochinvar Stage have been overlapped in this part. The lowest member of the stage here is a coarse conglomerate and sandstone, at least 600 feet thick, which is on about the same horizon as the Harper's Hill beds further north. Their thickness is rather difficult to estimate at all accurately on account of some doubtful faulting which occurs just north-east of Mt. View, but it is quite 600 feet, possibly more. This conglomerate was evidently deposited close to the old Carboniferous islands, the rocks of which have been described elsewhere.* The conglomerate is here followed by a development of basalt and tuffs, attaining a thickness of about 440 feet. The basalt contains numerous steamholes filled with such minerals as natrolite, datolite,† analcite, etc. The tuffs overlie the basalt, for the most part, and contain marine fossils. The position of the centre from which these basalts and tuffs were poured out, is doubtful. A couple of small patches of olivine basalt have been observed, quite isolated and in the midst of the acid volcanic rocks of the Carboniferous inlier of Mt. Bright. The most reasonable explanation of these occurrences seems to be, that they are old volcanic necks, and they may represent the old pipes from which this series was erupted. The tuffs are followed by 650 feet of calcareous mudstones. One hundred and fifty feet above the base of these mudstones, there is a well-marked development of limestone containing numerous well-preserved Foraminifera, which have been described by Messrs. Chapman and Howchin.‡

This bed of limestone is on the same horizon as those mentioned above(p.122). Ostracods are found in these beds, as well as numerous marine fossils, *e.g.*

Crinoid stems.
Stenopora tasmaniensis.
Fenestella(?), 2 or 3 species.
Protoretepora.
Spirifer tasmaniensis.
S. duodecimcostata
Martiniopsis subradiata.
Aviculopecten mitchelli.
Aviculopecten tenuicollis.
A. sprenti.
A. squamuliferus.
Deltopecten farleyensis.
Mæonia carinata.
Pachydomus, 3 or 4 species.
Ptycomphalina(?).

* Journ. Proc. Royal Soc. N. S. Wales, 1911, xlv., pp.379-408.
† C. Anderson, Rec. Austr. Museum, 1904, v., pp.127-130.
‡ Mem. Geol. Survey N. S. Wales Palæontology, No.14, 1905.

The other section of the Lower Marine Series to be described, is that obtained along the Eelah Road(Fig.3). Here, resting directly on Carboniferous rocks, there is a large development of mudstones and cherty shales. These attain a thickness of about 1,570 feet, and there has been an overlapping of more than 2,000 feet of strata below them. The mudstones are in the lower portion, and have been more easily eroded than the cherts, and so the former show few outcrops. The cherty shales, however, give good outcrops, and, near the top, a few marine fossils have been found. These include

Crinoid stems.
Spirifer tasmaniensis.
S. vespertilio.
Eurydesma cordata.
Pachydomus.
Platyschisma.

These shales are followed by about 350 feet of massive sandstone. This contains the equivalent of the Ravensfield Sandstone, which has been quarried extensively at Comerford's Quarry. This thick development of sandstones is similar to that mentioned near Farley Railway Station, and, as in that case, it has been included with the Farley Stage.

Above the sandstone, there is a thick series of basalt and tuffs. The basalt contains steamholes which have become filled with secondary minerals, such as calcite, natrolite, etc. The tuffs contain numerous fossils, amongst which are

Fenestella(?) *fossula.*
Stenopora.
Spirifer tasmaniensis.
Martiniopsis subradiata.
Eurydesma cordata.
Aviculopecten mitchelli.
A. tenuicollis.
Mæonia carinata.
Platyschisma oculus.

In the areas previously described, the development of basalt and tuffs has been confined to the Lochinvar Stage, but here there seems to be no doubt but that the volcanic activity took place during the deposition of the rocks of the Farley Stage. This area must have been close to the shoreline at this time, as indicated, by the abundance, in the tuffs, of thick-shelled molluscs, which inhabit shallow, turbulent waters. These tuffs are overlain by a series of a little over 300 feet of brownish sandstones, which are followed by the Greta Coal-Measures.

The Greta Coal-Measures.

Professor David mapped the outcrop of these Measures, and gave numerous detailed sections of the coal-seams developed at many points along the outcrop. At the time of publication of his work,* however, very little information was obtainable about the development between Branxton and Pokolbin.† Since that time, a new colliery (the Rothbury Colliery) has been opened, and the coal prospected at three other points along the outcrop on Rothbury Estate. To the manager of this colliery, Mr. Richard Thomas, Jr., I am indebted for most of the information contained in this section. The four separate points at which sections of the seams have been measured are :

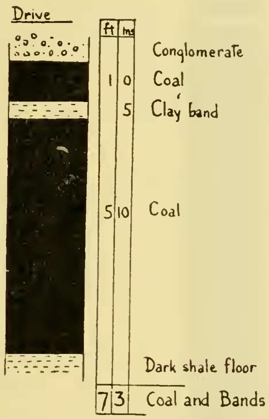

Fig 4 Section of Upper Seam at Rothbury Collieries

(1.) Rothbury Colliery (on portion 26, Parish of Branxton).

(2.) Where the outcrop crosses Black Creek.

(3.) In portion 17, Parish of Rothbury.

(4.) Where the outcrop crosses Rothbury Creek.

(1.) Rothbury Colliery.—As seen from Plate viii., the most complete section has been obtained at this point. Underneath a solid conglomerate-roof, there is a 7 feet 3 inches seam (see Fig.4).

* Mem. Geol. Survey N. S. Wales, Geology, No.4, 1907.

† *Op. cit.*, pp.138-140.

Exposure to the atmosphere gives a yellowish tinge to the surface of the coal from this seam, and a small amount of sulphur is deposited in the cracks. Although no crystalline pyrites has been observed, there is probably a small percentage of it in the coal; and this sulphur has been set free during the oxidation of the pyrites to iron sulphate ($FeSO_4$). This seam has a floor of dark shale, and then, for a thickness of about 60 feet, the strata are chiefly sandstones and a massive conglomerate. Then follows the best seam of this locality. Within a very short distance (only a few yards) of the outcrop, the seam is 12 feet 6 inches thick; and, at 170 yards in, along the tunnel, the seam has thickened to 14 feet $4\frac{1}{2}$ inches, including bands (see Fig.5).

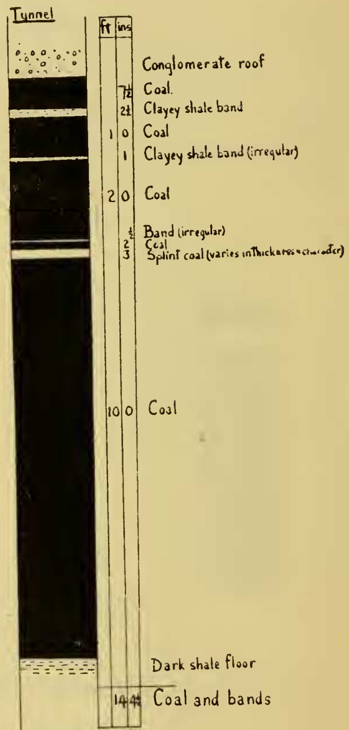

Fig 5. Section of coal seam at Rothbury Collieries

The lower ten feet of this seam is being worked at the Rothbury Colliery. The seam dips N.55°W. at $18\frac{1}{2}$°, and consists of hard, semibituminous coal.

Analyses of some Coals from the Lower Split of the Main Greta Seam.

	i.	ii.	iii.	iv.	v.	vi.
Hygroscopic moisture	2·35	1·87	1·54	2·38	2·10	1·58
Volatile hydrocarbons	40·74	40·63	42·05	41·01	41·45	42·72
Fixed carbon	51·11	50·52	49·29	51·70	49·74	50·30
Ash...	5·80	6·98	7·12	4·91	6·71	5·40
Sulphur	0·694	0·766	0·862	1·159	0·947	0·873
Sp.Gr.	1·290	1·303	1·304	1·282	1·251	1·272
Coke	56·91	57·50	56·41	56·61	56·45	55·70
Lbs. of H_2O converted to steam by 1lb. coal	13·5	13·5	12·9	13·3	13·0	13·5

i. Rothbury Collieries* (No.1 sample). Coke fairly swollen, firm and lustrous. Ash, grey in colour; semigranular.

ii. Rothbury Collieries* (No.2 sample). Coke fairly swollen, firm and lustrous. Ash grey; semigranular.

iii. Ebbw Main, Greta.† Bands picked out; coke fairly swollen, firm and lustrous. Ash buff-coloured; semigranular.

iv. Stanford Merthyr.‡ Coke slightly swollen, firm and lustrous. Ash buff-coloured; semigranular.

v. Pelaw Main.§ Coke well swollen, firm and lustrous. Ash light reddish tinge; semigranular.

vi. Hebburn.|| Coke fairly swollen, firm and lustrous. Ash pink; semigranular.

The above table gives analyses of two samples of coal from the Rothbury Collieries; and analyses, for comparison, from the same seam in four other collieries. The Rothbury coal is very suitable for gasmaking and steaming, and also makes a good coal for household purposes. It gives only a small percentage of small coal, and is a good coal for shipment, as it stands handling well.

This seam has a floor of dark shale, and the sandstone and conglomerate have been proved for about 20 to 24 feet below. Then there is a gap of approximately 20 feet, in which the strata

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* Analyses kindly supplied by Mr. Richard Thomas, Jr., Manager.

† E. F. Pittman, "The Coal Resources of New South Wales." Geological Survey of N. S. Wales, 1912, p.68.

‡ *Idem*, p.75. § *Idem*, p.73. || *Idem*, p.69.

have not been touched by prospecting shafts, but there is little doubt that this portion is composed of sandstone and conglomerate. Below this, the section is given in a shaft some 185 feet east of the main tunnel mouth. The section of this shaft is(Fig.6):

It shows a couple of weathered seams of coal, and a band of about one foot of kerosene-shale. In this lower part of the section, there is a sprinkling of small crystals of pyrites through the shale and sandstone, and also through the two feet of "Blackstone" at the bottom. The coal shown by the shaft is very weathered, and of no use; but it is, of course, possible that, further in from the outcrop, it may lose its weathered character. The greyish, shaly sandstone, between the seams, contains fairly abundant plant-remains, amongst which *Glossopteris* is the most prominent; some of the stems of these plants are replaced by pyrites.

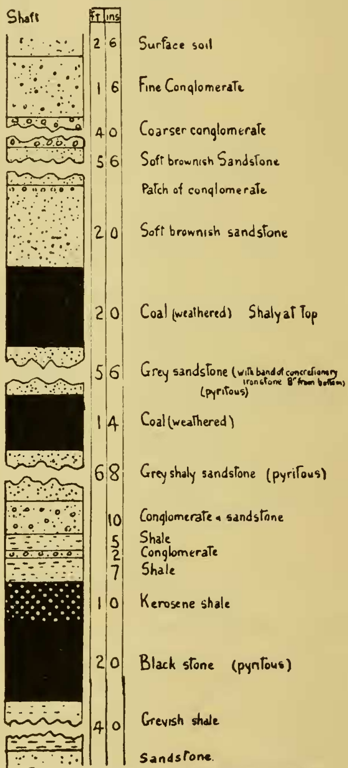

Fig 6 Section of Bottom Seams at Rothbury Colliery

(2.)Black Creek.—At Black Creek, about one mile south of the Rothbury Collieries, two seams can be seen, corresponding to the two upper ones at the first locality. The top one of these two seams has not been prospected, but a tunnel in the lower one revealed the following section(Fig.7, p.131).

It was near the position of this tunnel that Professor David had a shaft put down some years ago,* and obtained 9 feet, 9

* *Op. cit.*, p.139.

inches of coal and bands. The newer section gives a greater thickness of coal and bands (11 feet, 0½ inch), thus bearing out Professor David's opinion that the seam, being somewhat perished in his shaft, would probably be found to have a greater thickness.* There is a small band of white clay just below the top seam. The two seams at this point are about 40 feet apart, and their dip is N.47°W. at 24°.

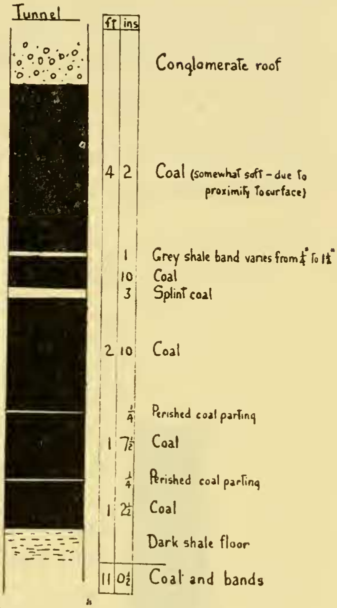

Fig 7 Section of Seam at Black Creek

(3.) Portion 17, Parish of Rothbury. – A small tunnel has been driven in portion 17, Parish of Rothbury, (about 1¾ miles south of the Black Creek tunnel), and a seam (with band) of 6 feet, 2 inches struck, giving the following section (Fig.8): –

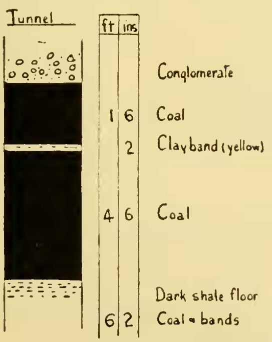

Fig 8 Section of Upper Seam on Portion 17 Par Rothbury

This seam is the equivalent of the top seam further north at the Rothbury Colliery. It does not quite attain the thickness of that seam, but, when exposed to the weather, the same yellow stain and sulphur-deposit are noted as at the Colliery. There is also a slight smell of H_2S in

* *Op. cit.*, p 140.

this old tunnel. These phenomena denote the presence of a small amount of pyrites in the coal.

(4.) Rothbury Creek.—Three-quarters of a mile further south, the outcrop crosses the Rothbury Creek. Here Professor David noted the outcrop of a coal-seam in the creek.‡ When I visited the spot, the outcrop in the creek was under water, but a shaft has been sunk for 39 feet, on the bank a few yards away, of which the following is a section(Fig.9):—

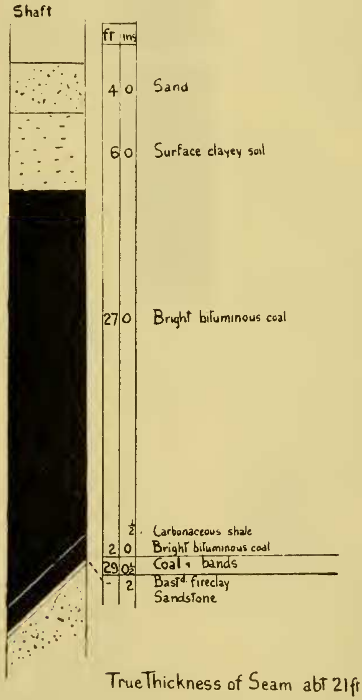

Fig 9 Section of Seam on bank of Rothbury Ck

It will be noted that the top boundary of the seam is horizontal, instead of dipping parallel to the bottom-edge. This indicates that the seam has been eroded somewhat. That this is so, is further indicated by the fact that, in the creek, there is a solid conglomerate dipping conformably just above the seam; while, in the shaft, there is no trace of the solid conglomerate, but only surface-sand and clayey soil. The seam dips N.60° W. at 45°, and has a thickness of at least 21 feet, and as the surface has been somewhat eroded, the thickness is probably somewhat more. It is a bright, bituminous coal of good quality, and

‡ *Op. cit.*, p. 140.

apparently does not deteriorate readily on exposure, as the shaft had been made over two years at the time of my visit, and the coal, which had been lying about for that time, showed only a slight amount of surface-discolouration; and when broken open, was as bright and hard as coal freshly taken out. About 75 yards up the creek, there is an outcrop of another seam, but the water was too high for me to see it. However, Mr. R. Thomas, Jr., informed me that he had got specimens of coal *in situ* at that point, when the creek had been drier. At the point in the creek where this outcrop occurs, the boulders in the creek-bed are all coated black, and there is a very strong smell of H_2S.

Plate viii. is a series of comparative vertical sections of the various seams just described. On comparison with section No. x,* accompanying Professor David's Memoir, there seems little doubt but that the top seam, in each case, represents the upper split in the main Greta seam. This is further confirmed by the presence of pyrites, which is indicated in these seams. The lower split of the main Greta seam appears to have become further split between Rothbury Creek and Black Creek, and a bed of conglomerate and sandstone, some 60 feet thick, is developed between the two parts. The 14 feet, 4½ inches seam at the Rothbury Colliery, and the 11 feet, 0½ inch seam at Black Creek, represent the top part of this lower split; and the lowest seams at Rothbury Colliery represent minor splits of the bottom-part of the lower split. The 21 feet seam at Rothbury Creek probably represents the whole of the lower split of the main Greta seam.

Summary of Greta Coal-Measures in this district.

The main Greta seam, or part of it, has been prospected in four places, and the seam is split as at other localities.

In each of the four localities, the upper split of the main Greta seam has been struck.

The lower split seems to be entire at Rothbury Creek, but splits further to the north.

* Section No. x is a comparative series of vertical sections of the Greta coal-seams.

The upper split contains a small amount of pyrites; in the top part of the lower split, no trace of this mineral has been observed; in the sandstone and "black-stone" associated with the bottom part of the lower split, there is a small percentage of pyrites.

The dips are in directions N.47°W. to N.60°W., and increase in amount as they get further south, *i.e.*, as they approach nearer to the eastern branch of the Elderslee fault. The band of conglomerate, between the two splits, appears to thicken very considerably towards the south.

The amount of perishing of the seams near the surface does not appear to be so great here as in the eastern and southern portions of the Greta Coal-Measures outcrop.

Upper Marine Series.

The Upper Marine Series, in the Hunter River District, occupies a much larger and more widely scattered area than the Lower Marine Series, and, for that reason, could not be studied in as much detail as the latter, in a comparatively short time. Examination of a number of the most typical exposures, however, enables one to form a fairly accurate estimate of the succession.

Whereas sedimentation in Lower Marine time was interrupted at frequent intervals by outbreaks of volcanic activity, in the Upper Marine of this district there were no such volcanic outbursts, and the sedimentation was uninterrupted. It must be remembered, however, that this is not true for other areas of Upper Marine sedimentation, *e.g.* in the South Coast District, there is abundant evidence of volcanic activity in Upper Marine time.*

The Upper Marine Series has been divided into three stages, namely, the Branxton, Muree, and Crinoidal Stages, by Professor David.†

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* Jaquet, Card and Harper, Rec. Geol. Surv. N. S. Wales, 1905, viii., Pt.1.—Card and Jaquet, Rec. Geol. Surv. N. S. Wales, 1903, vii., Pt.3.

† *Op. cit.*, p.319.

The lowest (Branxton) stage is from 3,000 to 3,200 feet thick, and follows immediately on the Greta Coal-Measures. This stage might be divided into two parts, (1) *lower*, with a thickness of about 1,400 feet; and (2) *upper*, 1,600 to 1,800 feet thick. The lower part consists of hard, massive, white to brown sandstone, often passing into conglomerate. In the lower 900 ft, the sandstone is often considerably iron-stained, and contains occasional bands of ironstone. At 900 feet from the base, there is a bed about 100 feet thick, of bluish-grey to brown mudstone, in which *Mytilus* and *Aphanaia* are common. Above this, there is a very hard, white sandstone, which forms a prominent outcrop near Black Creek, south of the railway line just west of Branxton. This particular bed is about 200 feet thick, and its outcrop is shown on the map. It contains a few marine fossils (e.g., *Spirifer*, *Martiniopsis*, and *Aviculopecten*), and numerous remains of plant-stems.

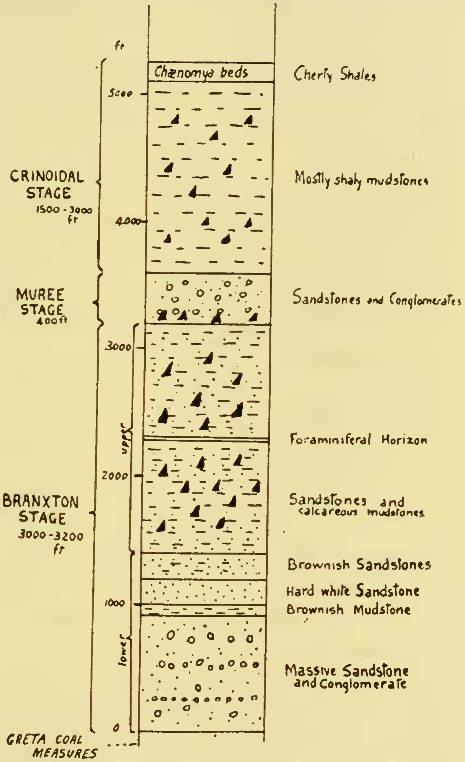

Fig 10.—Vertical Section of the Upper Marine Series.

The remainder of this substage consists of more brownish sandstones. Marine fossils occur abundantly in this lower part of the Branxton Stage, and, where conditions were favourable, they approach to within a few feet of the top seam of the Greta Coal-Measures. The following is a list of the fossils from this substage:—

Zaphrentis robusta.	*Strophalosia jukesi.*
Palæaster clarkei.	*Chænomya etheridgei.*
Protoretepora ampla.	*C. undata.*
Fenestella(?) fossula.	*Aviculopecten englehardti.*
Dielasma inversa.	*A. ponderosus.*
D. biundata.	*A. tenuicollis.*
D. hastata.	*A.* sp.
Spirifer convoluta.	*Deltopecten farleyensis.*
S. vespertilio.	*D. leniusculus.*
S. avicula.	*D.* sp. (juv.).
S. tasmaniensis.	*Seminula*(?).
S. duodecimcostata.	*Mœonia carinata.*
S. strzeleckii.	*M. valida.*
Martiniopsis oviformis	*Stutchburia costata.*
M. subradiata.	*Astartila polita.*
var. *transversa.*	*Leptodomus duplicicosta.*
var. *morrisii.*	*Platyschisma oculus.*
Productus brachythærus.	*Goniatites micromphalus.*

The upper half of the Branxton Stage is composed of sandstones and calcareous mudstones, with frequent shaly bands. They contain numerous glacial erratics, which sometimes attain a very large size, some of them being over two tons in weight. These beds are exceedingly rich in marine fossils, perhaps the most abundant being members of the Fenestellidæ(?). In them, at about 2,300 feet from the base of the Branxton Stage, occurs a limestone-horizon which contains numerous well-preserved Foraminifera.* This upper part is also characterised by an abundance of *Trachypora wilkinsoni*, which is only found sparingly on any other horizon of the Upper Marine, and is extremely scarce in the Lower Marine. Good outcrops of the

* Chapman and Howchin, "Monograph of the Foraminifera of the Permo-Carboniferous limestones of N. S. Wales." Mem. Geol. Surv. N. S. Wales, Pal., No. 14, 1905.

Branxton Stage can be seen almost anywhere, where it is shown on the map. A good occurrence of glacial beds has been exposed by the new road-cutting on the Branxton to Elderslee road, just before it reaches the Elderslee Bridge over the Hunter River. The following is a list of the fossils from this upper part of the Branxton Stage :—

Zaphrentis robusta
Crinoid stems.
Trachypora wilkinsoni.
Stenopora.
Protoretepora ampla.
P. konincki.
Fenestella(?) *internata.*
F. fossula.
F. plicatula.
Spirifer convoluta.
S. strzeleckii.
S. vespertilio.
S. stokesi.
S. tasmaniensis.
S. duodecimcostata.
S. sp.
Martiniopsis oviformis.
M. subradiata.
var. *konincki.*
Productus brachythærus.
Strophalosia jukesi.
S. gerardi.
S. clarkei.
Chænomya etheridgei.
Merismopteria.
Conocardium australe.
Aviculopecten tenuicollis.
Deltopecten fittoni.
D. leniusculus.
Aphanaia gigantea.
Mæonia carinata.
Pleurophorus morrisii.
Stutchburia costata.
S. compressa.
Platyschisma rotundatum.
Conularia.
Hyolithes lanceolatus.
Goniatites micromphalus.

The upper limit of the Branxton Stage is well-defined by the Bolwarra Conglomerate (" Muree Rock "), which forms the base of the Muree Stage. This is a massive conglomerate, on which very little grass or vegetation of any kind will grow, and which forms a bold, bare outcrop, very useful indeed for purposes of geological mapping. This conglomerate passes upwards to a hard, massive, somewhat calcareous sandstone, and the whole Stage attains a thickness of about 400 feet. Both the conglomerate and the succeeding sandstone contain numerous marine fossils, there being a most remarkable abundance, in places, of the small brachiopod, *Strophalosia*. The following is a list of fossils from the Muree Stage:—

Zaphrentis phymatoides.
Phialocrinus princeps.
Archæocidaris.
Stenopora crin ta.
Protoretepora.
Dielasma biundata.
D. amygdala.
D. cymbæformis.
D. hastata.
Productus brachythærus.
Spirifer convoluta.
S. clarkei.
Spirifer stutchburii.
S. duodecimcostata.
Martiniopsis cyrtiformis.
M. oviformis.
Strophalosia clarkei.
S. gerardi.
Conocardium australe.
Deltopecten leniusculus.
Mæonia fragilis.
M. carinata.
Entomis jonesi.

One of the best exposures of this Stage is in the vicinity of Mt. Vincent, just east of Mr. Charles Wyndham's residence at Wollong, at the place known as "Bow Wow." Here the Muree Beds weather into large caves or rock-shelters, where numerous fossils can easily be obtained.

Above the Muree Stage comes the Crinoidal Stage. This varies very considerably in thickness in places, having a minimum of about 1,500 feet, and a maximum of from 3,000 to 4,000 feet. For the most part, it consists of fairly soft shales and mudstones. These weather fairly readily, and in this lies the reason for the development of some of the extensive alluvial flats, *e.g.*, along the course of the Mulbring or Wallis Creek. For the same reason, good outcrops are not of as frequent occurrence as they are in the more resistant beds. They can be seen outcropping, however, near Mt. Vincent, and in the railway-cuttings and creeks to the west and south of Belford. In places, they contain small and large erratics; *e.g.*, where the old line of northern road crosses a small creek in portion 61, Parish of Rothbury, there are numerous, small erratics of such rocks as aplite, quartz-porphyry, quartzite, and fine-grained, black, basaltic rocks. A little further east, where the same road crosses Jump Up Creek, there are a number of large erratics, an aplitic one reaching quite three feet in diameter, and one about the same size, of coarse granite, containing grains up to nearly an inch long. These erratics are imbedded in brownish, calcareous mudstones, which also contain marine fossils. In this district, in the Crinoidal Shales there are two horizons, on which numerous specimens of the pseudomorph Glendonite occur, namely, (1) about 200 feet above the base (outcrop at Glendon), and (2) about 700 to 1,000 feet above the base (outcrops at Mt. Vincent and Singleton Railway Bridge). This stage terminates upwards in a series of hard, cherty shales, which have been quarried for road-metal, known as the Chænomya beds. These, as may be surmised from the name, contain large numbers of the fossil *Chænomya*; they also contain obscure casts of radiolaria. These Chænomya beds attain a thickness of 150 to 200 feet. The following is a list of fossils from the Crinoidal Stage:—

Zaphrentis phymatoides.
Archæocidaris, sp.ind.
Tribrachiocrinus corrugatus.
Stenopora crinita.
Protoretepora.
Fenestella(?).
Spirifer convoluta.
S. duodecimcostata.
Martiniopsis subradiata. var. *morrisii.*
Strophalosia.
Chænomya etheridgei.
C. audax.
C. mitchelli.
C. sp.
Deltopecten fittoni.
Eurydesma hobartense.
Mæonia carinata.
Goniatites micromphalus.

Notes on the Permo-Carboniferous Palæogeography in New South Wales.

During almost a year's study of the Permo-Carboniferous rocks of Eastern Australia in general, and New South Wales in particular, some facts with regard to the palæogeography have become apparent, which are contrary to the ideas generally held. This is especially so with the distribution of land and sea in New South Wales. It has generally been held that, in Permo-Carboniferous time, New England and north-eastern New South Wales were cut off from the main continental mass, and that there was a water-connection with Queensland, to the west of New England. Professor David expressed this view recently in his Presidential Address to the Royal Society of New South Wales, thus: "At this time [Permo-Carboniferous], Eastern Australia was probably, from New England to Townsville, isolated from the portion lying further to the west, first by the Permo-Carboniferous sea, and later by the lakes and swamps of that period."*

The following notes attempt to show the distribution of land and sea in New South Wales in Permo-Carboniferous time, as suggested by the results obtained by recent workers in the North-eastern portion of the State, particularly Mr. J. E. Carne, Professor Woolnough, and Mr. E. C. Andrews.

The ideas put forward are by no means to be regarded as final solutions of the problems, my chief reason for bringing them forward here being that they may serve as something tangible, to be modified as further information is brought to light. A very important area in connection with this subject, and one which is not well known at present, is that between the Manning and Clarence Rivers. When the various Palæozoic formations in this area have been determined and mapped correctly, it is probable that a number of modifications will have to be made in the maps presented here.

The results of recent work in Northern New England mostly show that the extensive series of shales and slates there, are of Permo-Carboniferous age,† and that the great granitic masses have intruded the Lower Marine rocks, and are thus of late Permo-Carboniferous or even Mesozoic age. These two results point to the fact, that the greater part of what is now northern New England, was under water in Lower Marine time. Other

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* Journ. Proc. Royal Soc. N. S. Wales, 1911, p.54.

† With regard to the slates in the neighbourhood of Tingha, two recent workers do not agree. Mr. L. A. Cotton[8] regards them as being older than Permo-Carboniferous, and similar to the Ordovician slates of Berridale and Tallong. Mr. J. E. Carne[7] puts them down as Permo-Carboniferous, evidently on account of their lithologic similarity to occurrences further north, in which he found Permo-Carboniferous fossils. Which of these views may be correct, however, does not affect these notes to any great extent, as it would only mean a small alteration in the position of the western limit of the Lower Marine Sea.

authors have noted deposits of Lower Marine age at a number of localities in that part of New South Wales east of New England, and north of the Hunter River. These localities are Rivertree[3], Drake[3], Joagla Falls (twenty miles east of Hillgrove)[1], near Kempsey[16], Wauchope, Kendall[6], and between Taree and Wingham[16]. These are all the known occurrences of undoubted Lower Marine rocks in New South Wales, outside those in the Maitland district[11], and near Mount Tangorin[11, 17]. Lower Marine fossils have also been found just over the Queensland border, six or seven miles west of Warwick. The distribution of these occurrences is shown on the map(Plate x.), and they seem to indicate that most of the north-eastern part of New South Wales was covered by the sea in Lower Marine time. The probable western limit of this sea has been drawn on the map. The faunas which exist at these occurrences, and the type of rocks developed, mostly indicate a relatively shallow sea, and also that the deposits were laid down not far from land. The faunas include typically such genera as *Spirifer*, *Martiniopsis*, *Eurydesma*, *Aviculopecten*, *Deltopecten*, *Pachydomus*, *Platyschisma*, etc. Sandstones and sandy mudstones are the most frequent and characteristic types of deposit; conglomerates are often developed, while limestones are comparatively scarce except in the Kempsey district. In the most northern part, the rocks have been altered subsequently, and now consist chiefly of slates.

The thickness of the strata which were deposited, shows that there must have been considerable high land not far away. One of the most prominent features of the land was a high range running approximately N.N.W., in the present Tamworth district, composed of rocks of Devonian and Carboniferous age. This range is probably responsible for the eastward bulge in the old coast-line towards Kempsey.

Parts of the district between the Macleay and Clarence Rivers, as well as the extreme north-east corner of New South Wales, are composed of old rocks, which are generally believed to be older than Permo-Carboniferous, but no fossils have been found in them. It seems more than probable, however, that this view is correct, and, therefore, a good deal of this area was probably a land-area during Permo-Carboniferous time. This leaves us with two alternatives as to the position of the Lower Marine Sea, and only detailed mapping of the areas mentioned can finally decide which is the correct view. These alternatives are, (1) that a land-mass constituted the north-eastern corner of New South Wales, and this was cut off from the mainland by a long narrow sea, the western coast of which was probably that shown on the map(Plate x.); or (2), that there was a long narrow peninsula, probably joined to the mainland somewhere between the Macleay River and Inverell, running in a general north-easterly direction to the Tweed River district, and that the Lower Marine rocks of northern New England and Drake were deposited in a large bay connected with the ocean on its northern side. Of these two alternative views, the former seems, to me, to be the more probable.

Towards the close of Lower Marine time, a slow pushing force began to make itself felt from a direction about E. by N. This may perhaps have been the first expression of the great movements which culminated eventually in the extensive granitic intrusions into the Permo-Carboniferous strata of New England. The result of this movement, pushing against the mainland to the west, was to elevate a belt roughly parallel to the old coast-line, and to depress somewhat the belt in between this elevated belt and the mainland.* The effect of this was the production of a land-zone extending in an approximately S. by E. direction from northern New England, and the depression of a zone between this and the mainland. The amount of depression, however, was not sufficient to submerge the old N.N.W. mountain range of Devonian and Carboniferous rocks near Tamworth, and this divided the submerged zone in two. Thus, there were produced relatively long and narrow inland depressions, in which the Greta Coal-Measures were deposited(Plate xi.). The presence

* This is somewhat the same effect produced by placing a sheet of paper flat on a table, with one end against a fixed object, and pushing the other end towards the fixed object. The first part of the paper to be elevated is a belt somewhere about the middle of the sheet, and parallel to the edge which is against the fixed object.

of the N.N.W. mountain range just mentioned, accounts for the absence of the Greta Coal-Measures between Wingen and Ashford.

In the Drake district, some of the marine deposits have a fauna which consists of a mixture of Lower Marine and Upper Marine types, and it seems almost certain that, during the time of deposition of the Greta Coal-Measures in the inland basins, marine sedimentation was going on in this area. This means that there was continuous marine sedimentation from Lower Marine into Upper Marine time in the Drake area.

After the deposition of the Greta Coal-Measures, the sea broke through the eastern land-barrier in its southern part, and submerged an area extending some distance north of Gunnedah, bounded on the west by the older rocks (Devonian, Silurian, and Ordovician) that we see at Marulan, Mt. Lambie, Bathurst, Wellington, etc. The northern shore of this arm of the sea was probably somewhere in the neighbourhood of the Peel Range and the Manning River, and the land for some distance north of the Manning seems to have extended further to the east than the present coastline. The Drake district was also submerged at this time, and the coastline appears to have been something like that suggested on the map(Plate xii.).

At the close of Upper Marine time, the pushing force once more made itself felt, and the result was that once again a land-barrier was raised, and another series of inland depressions formed. In New South Wales, the great inland basin in which the Upper Coal-Measures were laid down, was approximately as shown in Plate xiii., and it is probable that here, for the first time, there was direct water-communication from the Hunter River Basin to Queensland west of New England.

The land, at this time, to the east of the central part of the present coastline, was not far away, and must have been of some considerable height, as proved by the coarse conglomerates with diagonal bedding, dipping strongly inland, which Professor David has described at New Lambton and Red Head.*

* Mem. Geol. Surv. N. S. Wales, Geology, No.4, pp.20 and 41.

The Permo-Carboniferous was closed by the great granitic intrusions of New England and the great earth-movements which resulted in the production of the great Lochinvar Dome, the central part of which was raised through at least 6,000 feet.†

In conclusion, I wish to express my gratitude to Professor David for the interest he has always taken in this work, and for his willingness at all times to advise and help me in any way possible; also to Mr. W. S. Dun, by whose advice and assistance my work was often rendered easier than would otherwise have been the case, I wish to tender my most sincere thanks.

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† *Op. cit.* p.339.

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EXPLANATION OF PLATES VIII.-XIII.

Plate viii.

Comparative Series of Sections of Greta Coal-Seams south of Branxton.

Plate ix.

Geological Map of Part of the Hunter River District, taken from the Map accompanying Memoir of the Geological Survey of New South Wales, No.4; with Additions by A. B. Walkom, B.Sc.

Plate x.

Map showing approximately the Western Limit of the Lower Marine Sea in New South Wales.

Plate xi.

Map showing approximately the Distribution of the land and sea during the deposition of the Greta Coal-Measures in New South Wales.

Plate xii.

Map showing approximately the extent of the Upper Marine Sea in New South Wales.

Plate xiii.

Map showing approximately the extent of the inland sea, in which were deposited the Upper Coal-Measures.